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Uribe-Morfin, Paulina

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ORIGINAL ARTICLE

The invisible enemy: Understanding bird-window strikes through citizen science in a focal city

Paulina Uribe-Morfin¹ | Miguel A. Gómez-Martínez² | Lilia Moreles-Abonce¹ |
Anael Olvera-Arteaga¹ | Harumi Shimada-Beltrán³ | Ian MacGregor-Fors⁴ 

¹Desarrollo y Gestión Interculturales, ENES Unidad León, Universidad Nacional Autónoma de México, Guanajuato, Mexico

²Instituto de Biotecnología y Ecología Aplicada (INBIOTECA), Universidad Veracruzana, Veracruz, Mexico

³Ciencias Agrogenómicas, ENES Unidad León, Universidad Nacional Autónoma de México, Guanajuato, Mexico

⁴Red de Ambiente y Sustentabilidad, Instituto de Ecología, A.C. (INECOL), Veracruz, Mexico

Correspondence

Ian MacGregor-Fors, Ecosystems and Environment Research Programme, Faculty of Biological and Environmental Sciences, University of Helsinki, Niemenkatu 73, FI-15140, Lahti, Finland
Email: ian.macgregor@helsinki.fi

Present address

Ian MacGregor-Fors, Ecosystems and Environment Research Programme, Faculty of Biological and Environmental Sciences, University of Helsinki, Lahti, Finland.

Abstract

Bird-window collisions have been estimated to be among the most important sources of bird death. Despite increasing knowledge in Latin America, our understanding of this phenomenon is still incipient, with research performed in Mexico limited to a handful of studies. Here, we present the results of a citizen science effort focused on bird-window collisions at seven buildings in the university campus of the National School of Higher Studies (ENES) of the National Autonomous University of Mexico, located in the city of León (central Mexico). Our main goal was to describe seasonal patterns of bird-window collisions and their relationship with building traits (i.e., building height, window area) through citizen science monitoring strategies. Our results showed that collisions were higher in two of the seven studied buildings, with two bird species recording almost half of the total collisions: Clay-colored Sparrow (*Spizella pallida*) and Indigo Bunting (*Passerina cyanea*). Seasonally, April was the only month to differ from the rest of the studied months, showing significantly higher rate of bird-window collision. Regarding building traits, only building height was related to the number of recorded bird-window collisions. In sum, our study provides findings from an understudied area, showing the value of citizen science approaches to generate knowledge on a deadly phenomenon. Notably, besides the potential drawbacks and importance of generating this kind of information, our project raised awareness on the topic across the entire campus community, from the students and academics to the administration, highlighting the potential for social impact with these kinds of projects.

KEYWORDS

anthropogenic disturbance, avian mortality, bird-window collisions, migratory birds, urban ecology

1 | INTRODUCTION

Since the Industrial Revolution, human activities have increasingly affected our planet in such a way that scientists have identified them as a global geological and morphological force (Crutzen, 2016; Steffen, Crutzen, & McNeill, 2007). This new human-driven geological period, the Anthropocene (Crutzen, 2002; Lurance, 2019), has experienced a unique moment when the majority of the global human population passed from being nonurban to urban at the beginning of the 21st century (Grimm et al., 2008). Since then, cities have sprawled and new settlements have been established, with urban systems representing one of the pinnacle examples of human environmental alterations, considered irreversible in the human timescale (McKinney, 2006; Seto, Fragkias, Güneralp, & Reilly, 2011). Currently, urbanization and urban metabolism have been identified among the main reasons behind species endangerment globally (Fischer, Schneider, Ahlers, & Miller, 2015) and have been related to the main components of global change (e.g., land-use change, shift of biogeochemical cycles, biological invasions and climate change; Grimm et al., 2008).

Cities represent important ecological, and even physical, barriers for wildlife species and thus can act as a semi-permeable filter that imposes different constraints for regional biotas (Aronson et al., 2014, 2016; Croci, Butet, & Clergeau, 2008; MacGregor-Fors, 2010). In the case of birds (one of the focal groups that have received the most research attention in urban settings; Marzluff, 2016; McKinney, 2008), an important proportion of species are filtered in urban areas, with some groups being more affected than others (Aronson et al., 2014; La Sorte et al., 2018). Avian species that interact with cities and towns, including those that use urban vegetation for roosting only or those that dwell in large urban greenspaces (see Blair, 1996; Fischer et al., 2015 for a categorization of responses to urbanization), are subject to a number of hazards that are different in nature and intensity when contrasted with those of non-urban systems (Santiago-Alarcon & Delgado-V, 2017).

Urban-related hazards for birds are numerous and complex. Among the most evident ones, depredation of nests and adults—mainly by cats—, changes in health issues related to urban pollution, propensity to contract parasitic diseases and collisions with windows and vehicles head the list (Santiago-Alarcon & Delgado-V, 2017). In particular, bird-window collisions have been estimated to kill one billion birds annually in the United States alone (Klem, 1990; Loss, Will, Loss, & Marra, 2014), and at least 25 million in Canada (Machtans, Wedeles, & Bayne, 2013). Interestingly, estimations for the rest of the world are largely lacking due to the nonexistence of local

information to support them (Gómez-Martínez, Klem, Rojas-Soto, González-García, & MacGregor-Fors, 2019).

Despite previous predictions that window characteristics could drive bird-window collisions, the transparency or reflectiveness of panes has not been shown to determine accidents (Klem, 1989, 2014); although reflective glasses associated with abundant surrounding vegetation can potentiate the number of accidents (Kummer, Bayne, & Machtans, 2016a, 2016b). Collisions occur because birds are unable to identify window obstacles as a threat and subsequently try to fly through them with the aim of reaching the area reflected in the panes. A diverse set of factors have been associated with the frequency of collisions, including the ecological conditions and the architectural traits of buildings, as well as some behavioral characteristics of birds (Klem, 1989; Loss et al., 2019). Recently, artificial night lighting has been suggested to be a potential source of bird-window collision mortality, especially for nocturnal landbird migrants (Lao et al., 2020). In general, collisions occur at building windows, but have also been recorded in large numbers at small panes located in one-story homesteads, as well as other reflective urban structures (Zyśk-Gorczyńska, Skórka, & Żmihorski, 2020).

Although bird-window collisions are of the utmost conservation concern, they have not received the deserved attention outside of the United States and Canada. However, some regions like Latin America have started to fill some gaps in our comprehension of this phenomenon, additionally testing the effectiveness of deterrent methods to avoid collisions from happening (e.g., Brisque, Campos-Silva, & Piratelli, 2017; Ocampo-Peñuela, Peñuela-Recio, & Ocampo-Durán, 2016; Oviedo & Menacho-Odio, 2015). Studies in Latin America have also focused on relating potential drivers with bird-window collisions in university campuses and private homesteads (Agudelo-Álvarez, Moreno-Velasquez, & Ocampo-Peñuela, 2010; Rebolol-Ifrán, di Virgilio, & Lambertucci, 2019), as well as in building complexes located at nonurban preserves (Menacho-Odio, Garro-Cruz, & Arévalo, 2019; Ocampo-Peñuela et al., 2016). Despite the enormous importance of these initial studies, our knowledge is still incipient in the region, which is worrisome given that Latin America is home to the largest number of avian species globally (BirdLife International, 2013; Mittermeier, Turner, Larsen, Brooks, & Gascon, 2011).

To the best of our knowledge, studies assessing bird-window collisions have generally been performed by trained biologists and/or ecologists. Most recently, studies have included volunteer and/or citizen science efforts (e.g., Brisque et al., 2017; Kummer et al., 2016a, 2016b; Menacho-Odio, 2015; Nichols, Homayoun, Eckles, & Blair, 2018; Rebolol-Ifrán et al., 2019). Also, large projects

are currently using data provided by citizen scientists in the United States and Canada, such as the Fatal Light Awareness Program–FLAP, Chicago Bird Collision Monitors, and Bird Safe Portland (Loss, Will, & Marra, 2015). Undoubtedly, the importance and benefits of citizen science are reflected in the considerably increasing number of datasets that cover growing terrain. Most importantly, these projects often include environmental education components, which have been shown to be of the utmost importance in conservation biology (Bonney et al., 2014). Thus, given the concentration of people in cities and the importance of this increasingly valued research tool in ecological research (Dickinson, Zuckerberg, & Bonter, 2010), citizen science is a highly promising avenue for bird-window collision research and further management and policy.

Our knowledge regarding bird-window collisions in Mexico is limited to two studies that list colliding birds at university buildings (Cupul-Magaña, 2003; Gómez-Moreno, Herrera-Herrera, & Niño-Maldonado, 2018) and one that assesses some ecological variables related to collisions (Gómez-Martínez et al., 2019). In this study, we performed a citizen science survey of bird-window collisions at seven buildings in the university campus of the National School of Higher Studies (referred to as ENES hereafter due to its acronym in Spanish) of the National Autonomous University of Mexico (referred to as UNAM hereafter due to its acronym in Spanish) located in the city of León (Guanajuato). Our main goal was to describe seasonal patterns of bird-window collisions and to related building traits (i.e., building height, window area) through citizen science monitoring strategies. Based on previous studies, we expected to find higher bird-window collision rates in higher buildings with greater window area and lesser non-window facade area.

2 | METHODS

We conducted this study at the ENES-UNAM, León campus, located in the southernmost periphery of the city of León (21°02'37.6"N, 101°40'19.9"W; 1,785 m above sea level; Figure 1). This campus started its construction recently, in 2011, and has an extension of approximately 60 ha, with nearly half of it built. Previous to its urbanization, the location was part of a potato crop field, which currently surrounds the campus. After the settlement of the campus, three afforestation efforts were carried out: (a) 2012–2013, focused on the parking lot and at the back and front of the Buildings A and B, (b) 2018, at the Academic Tower, as well as the hall of the Physical Therapy and Odontology buildings, the Library, and the Coffee Shop, and (c) 2019, in front of the Academic Tower and Building C.

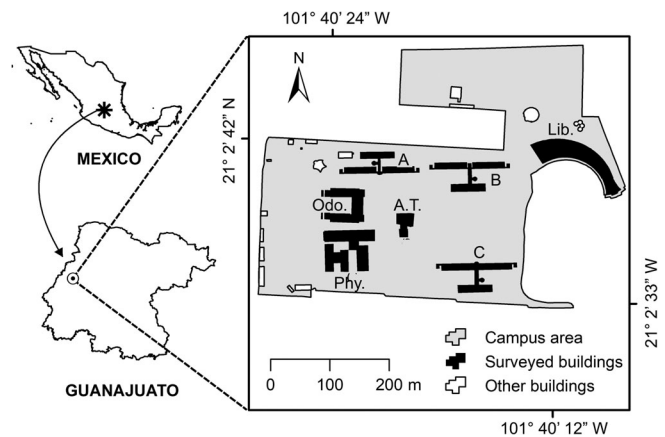


FIGURE 1 Survey map of the ENES (National School of Higher Studies) campus showing the location of all buildings in the university campus. A, Building A; B, Building B; C = Building C*; Lib., Library; Odo., Odontology Building; Phy., Physical Therapy Building; A.T., Academic Tower; *Building C was surveyed, but in a lesser proportion than the rest of the buildings; for this reason, we decided to exclude it from the statistical analysis

Currently, woody vegetation in the campus is composed of approximately 1,244 individuals, with the most representative being silky oak (*Grevillea robusta*), Mexican ash (*Fraxinus uhdei*), jacaranda (*Jacaranda mimosifolia*), golden rain tree (*Koelreuteria paniculata*), Brazilian peppertree (*Schinus terebinthifolia*), flamboyant (*Delonix regia*), Mediterranean cypress (*Cupressus sempervirens*), red oak (*Quercus rubra*), Peruvian peppertree (*Schinus molle*), fernleaf acacia (*Acaciella angustissima*), yellow oleander (*Cascabela thevetia*), southern live oak (*Quercus virginiana*), bead tree (*Melia azedarach*), and Brazilian orchid tree (*Bauhinia forficata*). In addition, recent efforts have set gardens as shelters for wildlife and pollinators across campus.

We concentrated survey efforts in the seven principal buildings of the campus: Buildings A, B and C, Library, Physical Therapy, Odontology and Academic Tower (Figure 1). For each building, we considered the following architectural variables: (a) constructed area (m²); (b) window area on all building facades (m²) and (c) building height (m) (Table 1). In order to gather as much information as possible, we invited a group of active students enrolled in different careers to check buildings for dead birds close to the windows of the seven focal buildings. PU-M, LM-A, AO-A and HS-B led the team of volunteers, consisting of 24 students. Initially, the volunteer team performed a check for previously collided individuals with the intention of assuring the intensive clean-up procedure suggested by Hager and Cosentino (2014). Volunteers surveyed buildings as periodically as possible from January 16 to November 20,

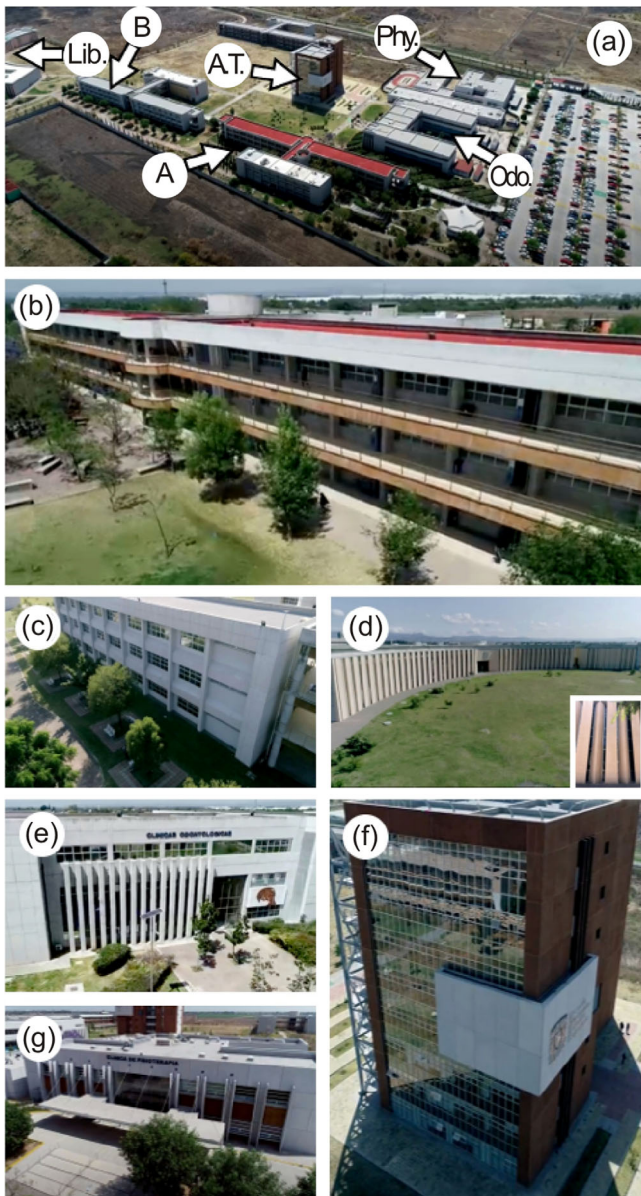


FIGURE 2 (a) Aerial view of ENES (National School of Higher Studies) campus and close up of each survey building: (b) Building A; (c) Building B; (d) Library; (e) Odontology Building; (f) Academic Tower; (g) Physical Therapy Building. Photo credit: Social Communication Area ENES-León [Color figure can be viewed at wileyonlinelibrary.com]

2019. They searched for bird carcasses near windows (less than 5 m perpendicular to windows; although one individual was found dead with clear collision markings at 8.8 m from the closest window). It is notable that given that most volunteers are not from León and head back home during summer and winter vacations, we do not have data for July and December, when the campus remains closed. Upon encountering a bird carcass, volunteers sent pictures (i.e., full-body ventral and dorsal, and face close-up) for further identification to IM-F. To assure that found carcasses corresponded to the result of bird-

window collisions, we sought for signs of the lethal accident, such as broken bills or signs of blood on the nostrils and/or beak (Klem, 1990), as well as measuring the distance between carcasses and building facades (Hager & Cosentino, 2014). Given that sampling effort per volunteer differed, we asked all volunteers to quantitatively score their participation, with which we generated a survey effort correction factor by building (Table 1). Briefly, we multiplied the average time invested in revisions by the average number of days surveyed per building. We then considered the maximum sampling effort value as reference to calculate the under-representation of the remaining buildings in relation to the reference value, representing the correction factor. Finally, we multiplied the observed number of bird-window collisions per building by the correction factor. Results of these procedures were derived in corrected number of collisions per building, which were considered for further analyses (Table 1).

We categorized all avian species found to have collided with windows at the assessed focal buildings in relation to their migratory status in the study area (*sensu* Howell & Webb, 1995). To assess differences in the number of collisions among months and among buildings, we performed χ^2 tests followed by post hoc assessments contrasting standard residuals compared to the *z*-value for a normal distribution. We also conducted Spearman's rank correlations to assess relationships between construction area, window area and height of each focal building and the sample-effort corrected bird-window collisions. We ran all analyses in R (R Core Team, 2019). Notably, given that building C was the least surveyed and for which very few collisions were recorded, we did not include it in our analyses.

3 | RESULTS

We recorded a total of 69 lethal collisions of 24 species resulting of bird-window collisions at the ENES-UNAM León campus through 1 year (excluding July and December) (Table 2). Considering the migratory status of the collision victims, we found a higher proportion of migratory species (59%; $n = 41$) in relation to resident ones (41%; $n = 28$). Species accounting for the most collisions (46.3%) were two ground-feeding migrant granivores: clay-colored sparrow (*Spizella pallida*) and indigo bunting (*Passerina cyanea*). Species for which we recorded more than one casualty are: mourning dove (*Zenaida macroura*), lazuli bunting (*Passerina amoena*), Inca dove (*Columbina inca*), broad-billed hummingbird (*Cyanthus latirostris*), American kestrel (*Falco sparverius*), barn swallow (*Hirundo rustica*), Lincoln's sparrow (*Melospiza*

TABLE 1 List of the surveyed buildings in the ENES (National School of Higher Studies) campus, their constructed building area, window area and building height, as well as sampling effort and sample-effort corrected bird-window collisions

| Building | Facade area (m ²) | Window area (m ²) | Building height (m) | Corrected bird-window collisions |
|------------------|-------------------------------|-------------------------------|---------------------|----------------------------------|
| Building A | 1,533 | 737 | 12.8 | 16 |
| Building B | 1,533 | 737 | 12.8 | 32 |
| Building C | 1,533 | 737 | 12.8 | 1 |
| Library | 3,246 | 2016 | 10.1 | 4 |
| Physical Therapy | 1,578 | 411 | 9.9 | 1 |
| Odontology | 2,628 | 533 | 9.56 | 5 |
| Academic Tower | 4,223 | 1,516 | 35.3 | 34 |

TABLE 2 List of bird species recorded on survey buildings as lethal victims of collisions, showing the number of casualties and the migratory status of each species

| Common name | Scientific name | Observed lethal collisions | Migratory status |
|----------------------------------|--------------------------------|----------------------------|------------------|
| Clay-colored sparrow | <i>Spizella pallida</i> | 19 | Migratory |
| Indigo bunting | <i>Passerina cyanea</i> | 13 | Migratory |
| Mourning dove | <i>Zenaida macroura</i> | 5 | Resident |
| Lesser goldfinch | <i>Spinus psaltria</i> | 4 | Resident |
| Lazuli bunting | <i>Passerina amoena</i> | 3 | Migratory |
| Inca dove | <i>Columbina inca</i> | 2 | Resident |
| Broad-billed hummingbird | <i>Cynanthus latirostris</i> | 2 | Resident |
| American kestrel | <i>Falco sparverius</i> | 2 | Resident |
| Barn swallow | <i>Hirundo rustica</i> | 2 | Resident |
| Lincoln's sparrow | <i>Melospiza lincolnii</i> | 2 | Migratory |
| Bronzed cowbird | <i>Molothrus aeneus</i> | 2 | Resident |
| Blue grosbeak | <i>Passerina caerulea</i> | 2 | Resident |
| Grasshopper sparrow | <i>Ammodramus savannarum</i> | 1 | Migratory |
| Black-chinned hummingbird | <i>Archilochus alexandri</i> | 1 | Migratory |
| Wilson's warbler | <i>Cardellina pusilla</i> | 1 | Migratory |
| Orange-billed nightingale-thrush | <i>Catharus aurantirostris</i> | 1 | Resident |
| Northern bobwhite | <i>Colinus virginianus</i> | 1 | Resident |
| Orange-crowned warbler | <i>Leiothlypis celata</i> | 1 | Migratory |
| Brown-headed cowbird | <i>Molothrus ater</i> | 1 | Resident |
| House sparrow | <i>Passer domesticus</i> | 1 | Resident |
| Cinnamon-rumped seedeater | <i>Sporophila torqueola</i> | 1 | Resident |
| Cassin's kingbird | <i>Tyrannus vociferans</i> | 1 | Resident |
| White-winged dove | <i>Zenaida asiatica</i> | 1 | Resident |

lincolnii), bronzed cowbird (*Molothrus aeneus*), and blue grosbeak (*Passerina caerulea*; Table 2; Figure 3).

We recorded the highest frequency of collisions at Building B ($n = 29$), followed by the Academic Tower (24 collisions; Table 1). Our analytical results show statistical differences in the number of collisions among

buildings considering the sample-effort correction ($\chi^2 = 69.61$, $df = 5$, $p < .001$). The post hoc analysis revealed that two buildings had a significantly higher number of collisions (Building B: residuals = 4.66; Academic Tower: residuals = 5.22), while three buildings had significantly lower collisions (Library: residuals = -3.17;

FIGURE 3 Examples of some of the bird-window collisions recorded on the surveys, such as (a) indigo bunting (*Passerina cyanea*); (b) barn swallow (*Hirundo rustica*); (c) American kestrel (*Falco sparverius*); (d) white-winged dove (*Zenaida asiatica*); (e) Lincoln's sparrow (*Melospiza lincolnii*); and (f) one example of the way in which we found the collided individuals close to the buildings. Photo credits: (a–b) HS-B, (c–e) PU-M, (f) Aarón Espinosa Jaime [Color figure can be viewed at wileyonlinelibrary.com]

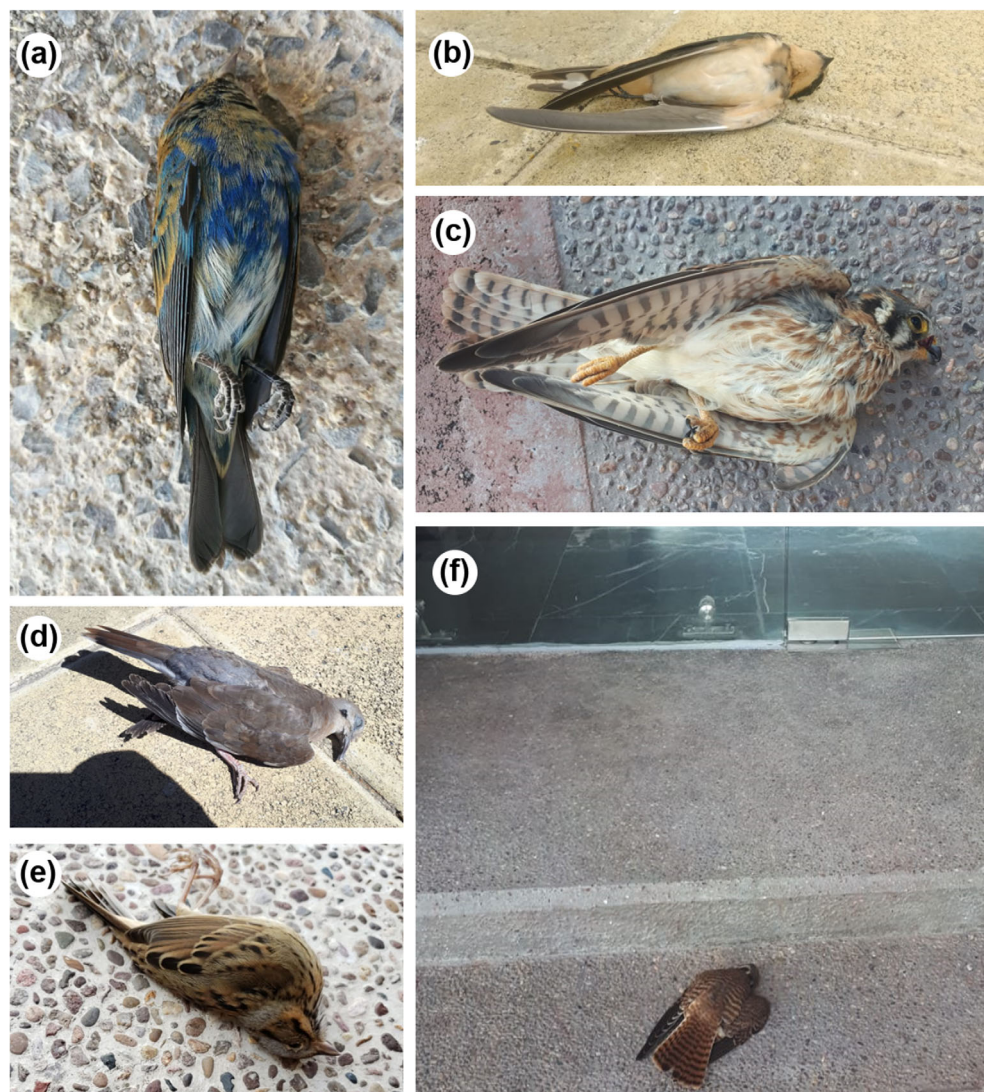
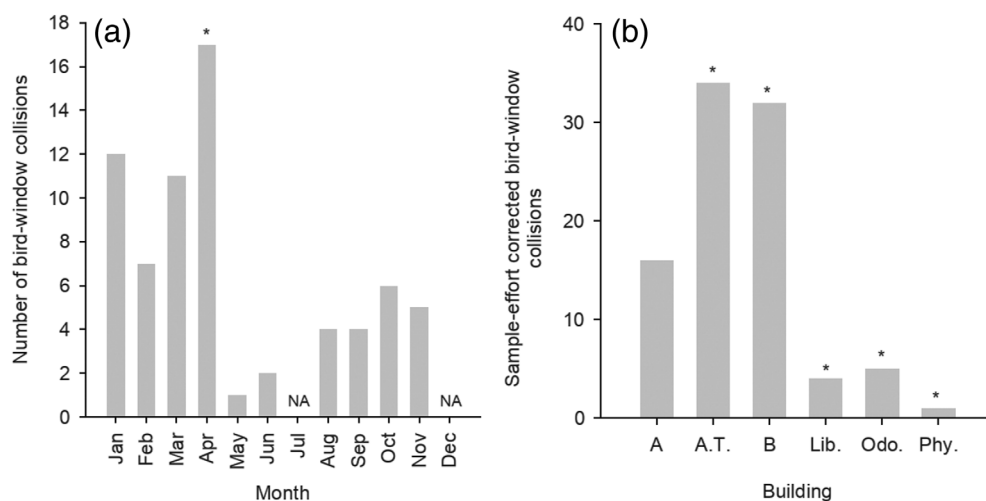


FIGURE 4 Graphs representing the number of collisions by month (a) and the sample-effort correction of collisions by building (b). Asterisks indicate the month or building with significantly differentiated number of collisions, according to the χ^2 tests. Abbreviations: A, Building A; A.T., Academic Tower; B, Building B; Lib., Library; Odo., Odontology; Phy., Physical Therapy



Physical Therapy: residuals = -4.01 ; Odontology: residuals = -2.89 ; z-value = $|2.63|$; Figure 4). When comparing the number of recorded bird-window collisions among months, we also found statistical differences

($\chi^2 = 32.60$, $df = 9$, $p = <.001$). In this case, the only month that differed significantly was April, with a significantly higher number of collisions than expected (residuals for April = 4.05 ; z-value = $|2.80|$). Spearman's rank

correlations showed a significant relationship between building height and bird-window collisions ($\rho = 0.81$, $p = 0.049$), but not with facade area ($\rho = 0.05$, $p = 0.91$) neither window area ($\rho = 0.40$, $p = 0.409$).

It is notable that we recorded that two additional species collided with windows in our study area, but they were only recorded in a pilot study performed some months after officially starting our standardized survey: rock pigeon (*Columba livia*) and loggerhead shrike (*Lanius ludovicianus*) were collision victims. Also, a male house sparrow (*Passer domesticus*) was found dead with signs of death by window collision, but we were not fully certain given that a predator seemed to have attacked it after the accident.

4 | DISCUSSION

Bird-window collisions have intrigued ornithologists, and even the general public, in recent times. Such interest seems to respond to the important amount of evidence-based knowledge that has been published in the past decade, shedding light on the magnitude of collisions and their role as drivers of the population decline of many species, including threatened ones such as the American woodcock (*Scolopax minor*; Loss et al., 2020). In this study, bird-window collisions concentrate in two of the studied buildings, with two bird species representing almost half of the total recorded strikes: the clay-colored sparrow and the indigo bunting. The clay-colored sparrow has few window collision reports in the literature (see Babilio, Moreno, & Piratelli, 2020). Yet, many other similar sparrow species have been recorded as important collision victims, such as the white-throated sparrow (*Zonotrichia albicollis*; Borden, Lockhart, Jones, & Lyons, 2010; Gelb & Delacretaz, 2006; Hager, Trudell, McKay, Crandall, & Mayer, 2008). The fact that ground granivores commonly collide with windows has been attributed to the fact that they are nocturnal migrants, making them a vulnerable group to strike while migrating by being attracted to artificial lights on buildings, as they use stars as navigational cues during nighttime (Borden et al., 2010; Lao et al., 2020). However, this is not the case of the many collided clay-colored sparrows, whose fatal events did not occur during the migration season, but occurred during the wintering season. Differently from the clay-colored sparrow, the indigo bunting has been identified as a recurrent collision victim in other studies from Mexico, the United States and Canada (Borden et al., 2010; Cusa, Jackson, & Mesure, 2015; Gómez-Martínez et al., 2019; Hager et al., 2008; Wittig et al., 2017). Interestingly, there are reports of this species having such site fidelity that after colliding with a

building window in Ontario (Canada) on May 13, 1975 and being banded before release, the same individual was found dead of a window strike on May 15, 1976 (Klem, 1990). Site fidelity has been found to occur in many bird species and, thus, the probability of species inhabiting nearby buildings could have a high probability of experiencing a fatal encounter with a window (Rodewald & Shustack, 2008). Also, as Kahle, Flannery, and Dumbacher (2016) showed in a study performed in San Francisco (CA, United States), migrants could be less familiar with local landscape conditions and configuration, and thus could make them more vulnerable to colliding with windows of recently constructed buildings (as those in our study area).

Although the two bird species that collided most with windows in our study area are migrants, we recorded significantly more collisions during the month of April, congruent with the beginning of the breeding season and the last part of the spring migration. This result agrees with previous studies that have reported more collisions during this season (Gelb & Delacretaz, 2006; Kahle et al., 2016; Loss et al., 2020; Schneider, Barton, Zirkle, Greene, & Newman, 2018). It has been proposed that this pattern could be related to birds having more active behavior, with increased speed of flight, differing dispersal patterns, and behavior related to nest construction and defense (Hager & Craig, 2014; Klem, 1989). Intriguingly, there are some species that are present and abundant in the study area of which we did not find a single collision event. For instance, common ravens (*Corvus corax*) not only overfly and fly among buildings, but some individuals even nested in one of the focal buildings of this study. Other species such as the house finch (*Haemorrhous mexicanus*) and the black vulture (*Coragyps atratus*) perch on the buildings, often on window ledges. In the case of common ravens, they were even nesting close to the windows; however, none of these species was found as collision victims despite being so close to the windows.

Regarding building traits, we only found building height to be related to the number of recorded bird-window collisions. This result is in line with many previous publications, suggesting that taller buildings represent an important driver of the phenomenon (Riding, O'Connell, & Loss, 2019). Yet, it is notable that in our study area, Buildings A and B are architectonically identical, but Building B doubled the number of collisions when contrasted with Building A. This suggests that the spatial location of buildings or the landscape components surrounding them are also important to consider in further assessments (Klem, Farmer, Delacretaz, Gelb, & Saenger, 2009).

It is notable that buildings for which we had good sampling effort where we recorded less casualties

(i.e., Library, Physical Therapy, Odontology), all have structures such as “mullions”. Previous evidence has suggested that these types of structures are related to a considerably lower proportion of bird-window collisions when contrasted with buildings lacking them (Gómez-Martínez et al., 2019; Kahle et al., 2016). Thus, our findings add to the body of knowledge that mullions and architectural structures that reduce the visibility of windows can be potential alternatives to reduce collisions on existing buildings known to represent a threat to birds.

Our study provides relevant findings from an understudied area based on a citizen science approach. Albeit given the approach we were not able to gather information for some periods of the year and had to exclude one building from our analyses, the amount and quality of the information, driven by the interest of participants, was more than enough to perform a rigorous assessment. It is notable that volunteers ought to know the protocols and information to gather upon a fatal encounter (Bird et al., 2014). Also, all window-collisions need to be followed closely and curated in order to maintain information reliability (Dissanayake, Stevenson, Allavena, & Henning, 2019), for which many social media platforms allow real-time communication. But, besides the potential drawbacks and importance of generating this kind of information, this project raised awareness on the topic across the entire community on campus, from the students and academics to the administration. Is it noteworthy that besides the rising awareness of volunteers, their enthusiasm in developing the project and learning about this deadly phenomenon for birds reached the point of suggesting deepening further research. Thus, we confirm that the citizen science approach is not only a great way to gather data for further scientific analysis, but it is also a venue to inform urbanites on the magnitude of this worrisome ecological phenomenon (Kummer et al., 2016a, 2016b; Rebolo-Ifrán et al., 2019).

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CONFLICT OF INTEREST

The authors declare no conflicts of interest.

ORCID

Ian MacGregor-Fors  <https://orcid.org/0000-0003-3198-7322>

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